Wm Kelley

The Purification of Public Water Supplies

A COMPARISON IN METHODS, COSTS AND RESULTS

BY

JAMES HOWARD BRIDGE

AUTHOR OF
OZONE: ITS NATURE, PRODUCTION AND USES,
THE OZONE TREATMENT OF PUBLIC WATER SUPPLIES,
THE HISTORY OF THE CARNEGIE STEEL CO.,
ETC., ETC.

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THE PURIFICATION OF PUBLIC WATER SUPPLIES

The first filter for the treatment of large bodies of water for the supply of towns was started in 1829 by the Englishman, Simpson, for the Chelsea Water Company of London. Since that day the process has undergone but slight modification; though, when Bacteriology became a science, there came a better understanding of the action of filters and a demand for ever-increasing efficiencies, especially as regards the elimination of micro-organisms.

It is a coincidence that gas, another English invention, was first used for the illumination of cities and homes at about the same date; and this, too, until recent times, remained the best artificial luminant known. Then, in the eighties, came the electric light; and, later, gas was employed as a means of generating current. Thus the old became the servant of the new. With the electric light came machines, in 1886, that made possible the production of ozone in large quantities; and the fact was promptly utilized in attempts to remedy, on a commercial scale, the deficiencies of filters, which the new science of Bacteriology had revealed. These attempts, bravely continued during twenty years, failed—until recently. Now it looks as though, just as gas became the handmaid of electricity, filtration is to become subservient to ozonization, with increased comfort and safety to human life.

That ozonization as a means of purifying water has not progressed since 1886 as rapidly as has electric illumination is largely due to the fact that its advance was dependent upon, and, therefore, followed, the advances made in electric lighting. It was not until the closing decade of the century that the alternating dynamo was perfected and transformers devised for producing the high potentials requisite in ozone-making. Even as late as 1897 it required a K.W.H. of electricity to produce four grams of ozone. In 1904 twenty grams per K.W.H. were produced. In 1907 this had been increased to sixty grams, and then, for the first time, the ozonization of water on a large scale became a commercial possibility, and able to compete in dollars and cents with sand filtration. In terms of bacterial efficiency, ozonization had from the very outset so far surpassed filtration that it was regarded by hygienists as the only perfect means of sterilizing water without robbing it of the elements which made it desirable for human consumption.

Early Experiments.

The first experiments in the sterilization of water with ozone were made in France by De Meritens in 1886 by means of an extremely primitive apparatus. The ozone was produced by the laboratory toy known as an electric egg, energized by a Rumpkorff coil and an electric machine devised by the experimenter himself. The ozone was drawn by suction into a tower filled with glass balls, over which water was sprinkled in a fine spray by a number of tubes arranged in a circle inside the column. A little later Séguy repeated the experiments with a more efficient means of ozone production; and in 1891 Fröhlich, engineer of the firm of Simens & Halske, of Germany, took up the subject, and brought it out of the laboratory experimental stage almost into the domain of industrial practice. Fröhlich presented the results of his experiments in a note to the Electro-Technical Society of Berlin, in which he announced that the bacilli of anthrax, cholera and typhoid were destroyed by ozone. He also drew attention to the fact, since frequently observed, that the sterilizing gas first acts on the dissolved organic matter contained in the water, and, after oxidizing this, attacks the bacteria.

These conclusions were so striking that the German Imperial Board of Health authorized Dr. Ohlmüller to make a report on the influence of ozone on bacteria, which he did, verifying the statements of Fröhlich.

About this time an electrician named Schneller, who had been in the service of Siemens & Halske, developed some original ideas on ozone production and went to Holland. There he met Baron von Tindal, who owned a large dairy farm, and suggested to him that ozone might prove to be a means of preserving milk. Baron von Tindal enabled Schneller to test his ideas, and the first Schneller ozonizer was built. A long and costly series of experiments in the sterilization of milk by ozone followed, but the outcome was unsatisfactory; and Tindal's attention being drawn by the reports of Fröhlich and Ohlmüller to the sterilization of water, he turned Schneller's further efforts in this direction.

In 1893, Schneller, assisted by Van der Sleen, constructed, at the instance of Tindal, an apparatus for sterilizing water in large quantities at Oudshoorn, Holland. Dr. Van Ermengem attended the demonstration on behalf of the Belgian Government. In his report to the Minister of Agriculture and Industry, Dr. Van Ermengem states that five litres of ozonized air, having a concentration of fifteen milligrams per litre, completely destroyed 3,717 million anthrax bacilli contained in one litre of water. Complete sterilization of water charged with germs of cholera and typhoid resulted with smaller quantities of ozone. Indeed, the only bacilli he found even partially resistant to this sterilizing agent were the innocuous species, B. Subtilis and B. Ramosus, which are capable of withstanding immersion for several hours in water or steam at boiling point. After introducing into filtered water a great number of spores of B. Ramosus, so that the bacterial count was 28,000 colonies per cubic centimeter, he found that after ozonization eleven samples out of thirteen were sterile, two showing a single colony of the bacillus introduced, and one of them contained one colony of B. Subtilis. In other tests with 32,000 colonies per c.c., seventeen samples out of eighteen were found sterile after eight days of incubation at 37° C. Experiments with B. Coli were equally successful. Water charged with 7,830,000 of these bacteria per c.c. was completely sterilized, and twelve samples all failed to reveal the presence of a single micro-organism of this kind. After twenty-four hours' incubation, four tubes showed a single colony of B. Subtilis. The B. Coli, although introduced in such vast numbers as are never found in nature, had been completely destroyed.

The chemical changes effected by ozonization were equally striking. They are as follows:—

Analyses of Old Rhine Water at Oudshoorn Before and After Treatment.

(Parts per 1,000,000.)

	Direct from the River.	From the Cistern.	After Flitration.	After Ozonization.
Residue on evaporation.....	0.222	0.220	0.284	0.294
Chlorine	0.035	0.046	0.049	0.049
Albuminoid ammonia	0.00027	0.00015	0.00009	0.00006
Free ammonia	0.00010	0.00010	0.0003	0.
Nitrites	0.	0.	0.	0.
Nitrates	0.0006	0.0008	0.0014	0.0012
Permanganate	0.024	0.016	0.0100	0.005
Microbes per c.c.	10,802	18,991	385	0.
Color	Yellow.	Yellow.	yellow.	No color.
Odor	Faint.	Faint.	Faint.	Faint.
Appearance	Turbid.	Turbid.	Turbid.	Clear.

These results were made known in France, and Dr. Ogier, Director of the Public Laboratory of Toxicology, was sent by the French Government to Oudshoorn to induce Baron von Tindal to install his apparatus at the Exposition of Hygiene in Paris in 1895. There the qualitative results were the same as those obtained at Oudshoorn, but the electrical operation of the installation was better. In Holland it had been found impossible to ensure a continuously satisfactory working of the apparatus, owing to the breaking down of the dielectrics used. Subsequently Schneller devised a method of dispensing with dielectrics, using a liquid cell of known resistance in the circuit, and this was the method used in Paris.

The process was carefully investigated by Drs. Roux, Répin and Marmier, and the engineer-chemist, M. Marius Otto. Encouraged by the excellent biological results reported by these investigators, the Municipal Council of Paris authorized Tindal to install a purification plant at the St. Maur Waterworks at Joinville-sur-Pont, which is still in existence and in daily use for demonstration purposes.

A further trial of the Tindal-Schneller system was made in Brussels at the International Exhibition there in 1897. This was conducted by Professors Van Ermengem and Gerard, and yielded results corresponding to those previously reported.

Baron von Tindal is said to have been offered 8,000,000 francs for his process on condition of his demonstrating that it was commercial, and capable of operating under all circumstances continuously and efficiently. The mechanical defects inherent in the system, as then developed, prevented him from reaping this rich reward of his noteworthy services in sanitation, and he died comparatively poor, except in honor and fame.

Existing Systems.

Out of Baron von Tindal's demonstrations grew three rival systems of ozone setrilization. Dr. Marmier developed that of Marmier & Abraham, installed at Lille, Belgium, and also used in a Marseilles brewery and at the mines of Bolera, Mexico. M. Marius Otto founded the Cie. Française de l'Ozone, which is now under contract to furnish the city of Nice with 25,000 cubic meters of ozonized water a day. He has also established in Paris and at Niagara Falls factories for the production of vanillin by means of ozone. The third system growing out of Tindal's is that of Vosmaer, who had been in Tindal's employ, and who built a small ozonizing plant at Schiedam, afterwards removed to Nieuwersluis, and then to Rotterdam, where it now lies inoperative. The Dutch company controlling the Vosmaer system sold its rights to the United Water Improvement Company, of Philadelphia.

Tindal's system was acquired by Count de Frise, who has made a number of changes in its equipment and manner of operation, and formed the Sanudor Company, of Paris, to exploit it. This company owns the demonstration plant built by Tindal at Saint Maur, near Paris. Schneller associated himself with Van der Sleen, and built a plant at Ginneken, Breda, Holland. During this time Siemens & Halske continued their experiments under Fröhlich in Germany.

Tests with Deadly Germs.

All the water purification plants named have been subjected to similar tests to those just reported of the Tindal process, and more or less voluminous reports have been issued. The most crucial tests of all were those applied to the Siemens & Halske plants at Martinikenfeld and Weisbaden under the separate direction of the German Imperial Board of Health, of the Royal Institute for Infectious Diseases, and of Koch's Institute. These tests included the dangerous experiment of adding to the water under treatment enormous numbers of cholera, typhoid and other deadly germs. The results, as summarized in the following tables by Dr. Erlwein, chief electro-chemist of Siemens & Halske, are from a paper read by him before a technical society in Zurich, and reproduced in the "Scientific American" Supplement for May 7th, 1904:—

Imperial Health Bureau.

(Ohmüller-Prall.)

Date.	Number of Bacteria per c.c. Before Ozonization.	After Ozonization. Ordinary.	After Ozonization. Pathogenic.	Species of Bacteria.	
	38,330	8	0	Cholera.	Ordinary Spree and aqueduct water infected with cholera germs and boiled water infected with typhus germs.
	16,590	9	0	Typhus.	

Royal Institution for Infectious Diseases (Koch).

(Proskauer, Schüder.)

	Before.	After.		
12, 3, '02........	600,000	0	Cholera.	Water infected with pathogenic bacteria.
14, 3, '02........	600,000	0	Cholera.	
18, 3, '02........	600,000	0	Coli.	
25, 3, '02........	600,000	0	Typhus.	
2, 4, '02........	600,000	0	Typhus.	
27, 3, '02........	600,000	0	Dysentery.	

Koch's Institute.

Date.	Number of Bacteria per c.c. Before Ozonization.	After Ozonization.	Species of Bacteria.	
12, 7, '02.....	600,000	0	Coli.	Infected water.
16, 7, '02.....	600,000	0	Vibrios.	
17, 7, '02.....	600,000	0	Vibrios.	

The complete destruction by ozone of typhoid and cholera germs, thus artificially introduced into water in such vast numbers, is a striking demonstration of its great germicidal power. In the literature of water purification there is nothing to compare with it; for the only thing added to the water was electrified atmospheric air, and nothing remained in it as a result of the treatment except an increased proportion of free oxygen, which enhanced its hygienic properties.

Dilute Sewage Treated.

Hardly less astonishing are the results of a prolonged series of tests made in Philadelphia by Dr. Rivas, assistant bacteriologist of that city. These are reported in the "Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten," XVII. Band., 1906:—

The experiments were conducted with the water of the Schuylkill River below the city at 30th and Locust Streets, West Philadelphia where the plant is in operation. At this point the river is badly polluted, containing from 400,000 to 3,000,000 bacteria per cubic centimeter. Such a water may be regarded as diluted sewage. Before ozonization, this water was submitted to a rough sand filtration merely to remove some of the suspended matter.

No	Source	Gallons per Hour	Ozonized Air per Hour Cu. ft	Ozone per Cubic Meter of Air Gram	Bacteria per C.C. after 48 Hours at 19°-20° C
2.	Filtered	5,000	....	....	700,000
3.	Ozonized	5,000	6,000	0.9	200
4.	Ozonized	5,000	6,000	0.9	5
5.	Ozonized	5,000	6,000	0.9	7
6.	Control	....	....	....	0
1.	River	....	....	....	700,000
2.	Filtered	5,000	....	....	240,000
3.	Ozonized	5,000	5,200	1.0	17
4.	Filtered	7,500	....	....	250,000
5.	Ozonized	7,500	5,200	1.0	34
6.	Control	....	....	....	0

In view of the encouraging result in the last two experiments, in which by ozonization polluted water containing over 200,000 bacteria per c.c. was rendered practically sterile, it was suggested to increase the rate of supply in order to find out the maximum amount of water which could be purified with a definite concentration of ozone.

No;	Source	Gallons per Hour	Ozonized Air per Hour Cu. ft.	Ozone per Cubic Meter of Air Gram.	Bacteria per C.C. after 48 Hours at 19°-20° C.
1.	River	....	....	....	1,300,000
2.	Filtered	5,000	....	....	700,000
3.	Ozonized	5,000	5,200	1.0	460
4.	Filtered	7,000	....	....	1,300,000
5.	Ozonized	7,000	5,200	1.0	740
6.	Filtered	10,000	....	....	1,200,000
7.	Ozonized	12,000	5,200	1.0	1,500
8.	Ozonized	12,000	5,200	1.0	2,100
9.	Control	....	....	....	0

The fact that the percentage of removal of this abnormally polluted water is so great, indicates the most excellent results obtained by the process; and the fact that the resulting count in the ozonized water is high in this case should not detract from the method nor be discouraging to the inventor of the process, since in no case will a city be compelled to render potable a supply from such a source.

The result of this experiment suggested a repetition under a constant rate. The result was as follows:—

No	Source	Gallons per Hour	Ozonized Air per Hour Cu. ft.	Ozone per Cubic Meter of Air Gram	Bacteria per C.C. after 48 Hours at 19°-20° C.
1.	River	....	....	....	1,100,000
2.	Filtered.......	10,000	....	....	300,000
3.	Ozonized	10,000	5,200	1.0	4,300
4.	Filtered	10,000	....	....	600,000
5.	Ozonized	10,000	5,200	1.0	3,500
6.	Filtered	10,000	....	....	200,000
7.	Ozonized	10,000	5,200	1.0	110
8.	Filtered	10,000	....	....	400,000
9.	Ozonized	10,000	5,200	1.0	50
10.	Filtered	10,000	....	....	450,000
11.	Ozonized	10,000	5,200	1.0	35
12.	Control	....	....	....	0

No	Source	Gallons per Hour	Ozonized Air per Hour Cu. ft.	Ozone per Cubic Meter of Air Gram	Bacteria per C.C. after 48 Hours at 19°-20° C.
1.	River	....	....	....	1,200,000
2.	Filtered	10,000	....	....	300,000
3.	Ozonized	10,000	5,000	1.0	120
4.	Filtered	10,000	....	....	500,000
5.	Ozonized	10,000	5,000	1.0	55
6.	Filtered	10,000	....	....	500,000
7.	Ozonized	10,000	5,000	1.0	38
8.	Control	....	....	....	0

In the first of these experiments, though the action of ozone was not so effective at the beginning, it improved later, showing a reduction from 400,000 and 450,000 to 50 and 35 bacteria per c.c. respectively. This improvement was due very probably to the gradual washing of dirt or organic matter accumulated in the pipes. Likewise the same improvement is observed in the next experiment, which shows a reduction from 500,000 to 55 and 38 bacteria per c.c.

Selective Action of Ozone.

Having reached this point, the next step was to find out the kinds of bacteria which remained after ozonization, or in other words, to determine the selective action of ozone in eliminating all non-spore producing bacteria. A thorough study of this subject no doubt would have been a most instructive part of work, as regardless of a high bacterial content in a water, if the germs are of the harmless saprophitic type, such a water is of far better quality than another of low number of bacteria containing among them the pathogenic or disease producing germs.

Due to the limited time for these researches, the study of the colon group only was considered. No doubt with sufficient reason the number of this group in a water is taken as an indication of pollution. In the writer's opinion too much reliance is placed upon this point. The wide distribution of the colon group in nature, and especially the simple and imperfect routine technic frequently employed in some cases in its study, not only diminishes the importance of such results, but also almost entirely neglects the researches concerning the typhoid, cholera, pyocyaneus and some other pathogenic bacteria, inhabitants of the water far more important than the colon bacillus.

In the study of the colon bacillus beside the biological features, viz., pink colonies on litmus-lactose-agar, fermentation of glucose, production of indol, coagulation of milk, reduction of nitrates into nitrites and non-coagulation of the gelatine, the morphological characteristics were also considered, the cultures were examined under the microscope, fresh and stained, and submitted also to Grams method of staining.

It is not necessary to consider the details of the technic employed in the study of the colon group and the biological and morphological variations which it presents; all were thoroughly considered; it suffices only to say that, besides a sterile control of the water, the media used to culture of the colon and typhoid bacillus were submitted to exactly the same tests in order to eliminate any doubtful reactions. The results are as follows:—

No.	Source	Gallons per Hour	Ozonized Air per Hour Cu. ft.	Ozone per Cubic Meter of Air Gram.	Bacteria per C.C. after 48 Hours	No. of B. Coli per C.C. of Water
1.	River	....	....	....	900,000	48,000
2.	Filtered	800	....	....	400,000	16,000
3.	Ozonized . ..	800	6,300	0.6	6,000	50
4.	River	....	....	....	1,000,000	40,000
5.	Filtered	800	....	....	600,000	19,000
6.	Ozonized . ..	800	6,300	0.6	5,000	52
7.	River	....	....	....	800,000	35,000
8.	Filtered . ..	800	....	....	1,000,000	43,000
9.	Ozonized . ..	800	6,300	0.6	1,200	15
10.	River	....	....	....	500,000	31,000
11.	Filtered . ..	800	....	....	280,000	10,000
12.	Ozonized . ..	800	6,300	0.6	1,000	0
13.	Control	....	....	....	0	0

Here again as in the previous experiments is noted a gradual improvement in the ozonized water, the longer the plant was in operation, reducing the number of bacteria to 1,000 per c.c. of the ozonized water, and no colon bacillus in one c.c. of the same water; but the irregularity of the experiments in general, due to the changeable conditions of the river, and the variable removal of bacteria by filtration, made it advisable to repeat the experiment, which resulted as follows:—

No.	Source	Gallons per hour	Ozonized air per hour cu.ft.	Ozone per cubic meter of air gram	Bacteria per c.c after 48 hours at 19°-20° C.	No. of B. Coli 1 c.c	100 c.c.	500 c.c.	1000 c c
1.	River	....	....	....	40,000	3,000	..	..	..
2.	Filtered ..	800	....	....	[illegible]	1,000	..	..	..
3.	Ozonized .	800	4,500	0.9	2	0	0	0	0
4.	Control ...	....	....	....	0	....	..	..	..

In this experiment the efficient removal of bacteria by ozonization brought about the most satisfactory result, giving only 2 bacteria per c.c. of the ozonized water, and no coli bacilli, not only in 1 c.c., but also in litre of the water treated.

In conclusion one more experiment was made, as follows:—

No.	Source	Gallons per hour	Ozonized air per hr. cu. ft.	Ozone per cubic meter of air gram	Bacteria per c.c. after 48 hours at 19°-20° C.	1 c.c.	No. of B. Coli 10 c.c.	100 c.c.	500 c.c.	1000 c.c.
1.	River	....	....	....	3,000,000	10,000	..	..	..	..
2.	Filtered .	800	....	....	40,000	1,400	..	..	..	..
3.	Ozonized	800	6,000	0.6	5	....	0	0	0	0
4.	Control ..	....	....	....	0	....	..	..	..	..

Here, as before, a most favorable result was obtained, proving once more the effectiveness of ozone in the purification of badly polluted water.

The selective action of ozone in eliminating the colon group from the ozonized water may be taken as sufficient evidence that the same result would be obtained with the typhoid and cholera bacillus which have about the same resistance and vitality.

As shown in the above experiments, such a water may be regarded as diluted sewage. As far as the literature upon the subject is concerned, no one has ever attempted to ozonize such a foul water.

Chemical Changes Effected.

Though special attention was paid to the bacteriological examination, the chemical analyses were not entirely neglected. The results of some analyses made are as follows:—

Parts Per Million.

	Filtered water.	Oxonized water.
Total organic and ammonium (Kjeldahl method)	2,15	1,76
Nitrogen as—		
Nitrites	0,08	0,00
Nitrates	0,76	0,96
Permanganate consumed	10,86	7,11
Oxygen consumed	2,73	1,77
Oxygen dissolved	6,80	10,80
Chlorine	6,00	6,00
Carbonic acid	6,00	6,00
Hardness	96,00	96,00
Alkalinity	35,00	35,00
Iron, comparative test	equal.	

As shown by this result, there is a marked reduction in the organic matter. The marked increase in the "dissolved oxygen" is but natural, as is the fact that the inorganic constituents remain unchanged by ozonization.

(Signed) D. Rivas, M.D.

The water of the Schuylkill River at the point at which the foregoing tests were made contains more fresh organic matter than do the effluent discharges of some sewage works. The entire sewage of the northern part of the city of Philadelphia is discharged into the Schuylkill between an intercepting dam and the point from which water was taken for the above tests. Within a few hundred feet of this point the stock yards and slaughter houses of the city are located, and large quantities of fresh organic matter are discharged from them into the stream, so that its waters are often tinged with red. Nearby are several acres of stable manure heaps, collected by the railways for transportation beyond the city limits; and the seepage from these putrifying masses finds its way into the stream. The river at this point is simply an open sewer, and accumulations of organic waste pass slowly on each tide to and fro near the ozonizing plant. From the results shown by the foregoing experiments it may reasonably be inferred that ozonization will be found practicable, even in the final purification of effluents from sewage works before they are discharged into natural water courses. But for the present the purification of municipal water supplies is too urgently demanded to permit of experiments along this line.

How Ozone Acts.

The reason of the high bactericidal power possessed by ozone is extremely simple. Chemical analysis of the bodies of bacteria show that they are made up of 84 per cent. of water and about 16 per cent. of solids. Of these solids more than half consists of carbon. The strong affinity of oxygen for carbon is well known. Ozone, being a concentrated form of oxygen, has an even greater affinity for carbon; and the moment a bacillus comes in contact with a bubble of ozonized air the carbon of its body combines with oxygen, and the bacillus is consumed as completely as if it had touched a flame. Indeed, the process is analogous to that of combustion. Just as though burnt up, nothing remains of the bodies of bacteria but carbonic acid gas, which rises to the surface of the water and passes off into the air.

So, too, with much of the dissolved organic matter contained in the water, the invisible products of animal and vegetable decay. These are also largely oxidized. Discolored water is made bright and sparkling, and the putrescence resulting from decaying organic matter is removed, with its causes.

On the other hand, nothing of a deleterious nature is added to the water. Compounds of copper, sulphur and other injurious chemicals have no place in ozonization. Ozone-purified water is simply H_2O, with a little more free oxygen than is usually found in natural waters.

A Purely Mechanical Process.

To the foregoing advantages should be added that arising from the purely mechanical character of the process of ozonization. The elimination of disease germs from a city's water supply is not dependent upon the care and attention of dozens of unskilled laborers. It is not conditioned upon the thoroughness with which many acres of filtering areas are cleaned. It is not affected by the accuracy with which an Italian or Slav workman may remove an inch or two of a mud deposit. None of the elements of human liability to err are involved in ozonization. A skilled mechanic moves a switch, turns a few valves, watches the meters for a few moments, and then the entire system runs automatically day and night, with no further attention than the oiling of the bearings and the cleaning of the machinery. If need be, the doors of the building may be closed, and the machinery left to run itself. So far as mechanical perfection applied to hygienic ends can be reached, it is in the supplementing of filtration by ozone purification.

Dr. Leffman's Experiments.

The Philadelphia plant was also investigated by the well-known expert, Dr. Leffman, from whose report the following remarks are taken:—

I have made some tests of the process of purification of water by ozone, as exemplified by the plant operating at 30th and Locust Streets, in this city. The samples were taken from the plant by me and the examinations were made under conditions that made sure that no one connected with or interested in said plant could influence the results. In an inquiry of this character, the only important points are to determine the bacteriologic effect, and to determine the practicability of the operation.

The bacteriologic results were as follows, duplicate samples agreeing closely:—

Unfiltered water,	10,000	organisms	per	cubic	centimeter.
Filtered water,	10,000	"	"	"	"
Ozonized water,	2	"	"	"	"

By filtered water is here meant the water after it passes through the rough filters operated in connection with the plant. The figures show that, as is well-known, such filtration merely clarifies the water, that is, separates the coarser suspended matter, but does not render it sterile. The ozonization, it will be seen, kills all but a very insignificant number of bacteria.

A great advantage of this method is that it does not introduce any metallic substance into the water, nor does it affect the general chemical composition or its taste or color. The so-called alum process, introduces a notable amount of chemicals into the water, and the copper sulphate method lately proposed is still more objectionable.

The application of ozone to the purification of water is not an untried method. It has been well-known to chemists for many years that ozone is an active agent in the destruction of organic matter and that it kills many forms of life. As ozone is merely an active form of the common oxygen of the air, the supply of it is unlimited, the only difficulty being the cost of production.

The operation, as I have seen, seems to be simple and efficient. I see no reason to doubt that it can be carried out on a moderate, or on a large scale with equal certainty. It is capable of installation in units of convenient size, which by the addition of further units can be made to meet an increased output. In large operations scientific supervision will be required, but this is true of all large installations, and is especially true of slow sand filtration. The ozone process has the advantage over sand filtration systems, of requiring but little land and of being capable of establishment at almost any point, while sand filters can only be located where large areas of land are obtainable. Moreover sand filtration is made more difficult by the long winter season in this part of the world. The ozone process is easily operated so as to be independent of temperature.

(Signed) HENRY LEFFMAN.

Prof. Soper's Rep rt.

The evidence thus presented, that ozonization is an efficient means of sterilizing municipal water supplies, could be voluminously supplemented by numerous other reports made by scientists and official investigators in Europe and America; but there is no need to reiterate facts so frequently stated. Prof. Soper, of Columbia University, New York, however, occupies such an authoritative position in America that a resumé of the results of his investigations may fitly be quoted:—

"A conclusion of the facts here presented," he says, "leads to the conclusion that drinking water can be sterilized, and that unpleasant colors and odors arising from organic impurities can be removed by ozone. It remains to be shown what class of waters are best suited to the treatment and the conditions under which ozonization may be successfully carried on. The action of ozone in the artificial purification of water is a chemical one. It is unlike other methods in that no mechanical or biological actions contribute to the results. By ozonization, chemically active oxygen is brought into contact with oxidizable impurities, which thereupon suffer transformation into more staple compounds. No suspended matters are removed or destroyed, except the bacteria, and in this respect the ozone treatment differs from the most familiar methods of filtration and sedimentation. Consequently the class of waters susceptible of purification by ozone are generally free from organic particles. Such, for example, are clear, colored or foul-smelling surface or ground waters and the effluents of improperly-acting filters. The claims made for the ozone treatment of water are distinct, and its functions are as clearly defined as are those of filtration and sedimentation. Ozonization aims to eliminate bacteria from water, and to destroy unpleasant colors and odors of vegetable origin. From a consideration of all obtainable data I am led to the conclusion that this result is possible. The function of ozonization puts at a discount the possible ignorance and carelessness of filter-keepers, and places the responsibility for pure water in the hands of electricians and enginemen, whose familiarity with machinery makes them competent to manage the mechanical details of the process. There is no cleaning of apparatus in the ordinary case, no stopping, and little regulating to be done. The proper dose of ozone is known by the presence or absence of its peculiar odor when observed at the top of the water column. Ozonization is in no sense a straining process, and from its nature could not be expected to sterilize waters containing large quantities of matter in suspension. Consequently, for the proper treatment of water by ozone, filtration is in most cases indispensable, but the kind of filtration which may be termed a simple straining is as effective as any other in preparing water for ozonization. Of special importance is the completeness with which ozone destroys unpleasant odors in water. When filtered water or ground water is exposed to heat and light, forms of vegetation are apt to grow and cause trouble. Films of cloudy masses of algæ appear under such circumstances, and frequently cause fishy, pungent, aromatic or disgusting tastes and odors in the water. It seems certain that ozonization of such water, previously filtered to remove the objectionable organisms, etc., would return it to its former acceptable condition."

Disease Germs Killed First.

Concerning the character of the bacteria affected by ozonization, Dr. Wood-Smith, of London, employed as expert chemist by the Government of Great Britain, in a communication to the writer, says:—

"In considering the contamination of water by disease germs, one has only to deal with the bacteria, among which class of organisms are particularly the bacilli of typhoid fever and the vibrios of Asiatic cholera. Of other disease germs few are met with habitually in water, although, of course, they might occur accidentally; but in the case of typhoid fever and Asiatic cholera the disease virus is more often than not connected practically with the water supply, and it is with regard to these bacteria rather than others that the sterilization of water should be principally aimed.

"These bacteria are of the non-spore-bearing variety, their multiplication being caused by fission or direct division. This point is important from the water sterilizing point of view, as spore-bearing bacteria, of which anthrax can be taken as a typical example, are much less readily acted upon by sterilizing agents than their non-sporing brethren. This is because the spores, which form within the bacterial cell, on obtaining freedom, are possessed of an enhanced vitality, and are thus able much more readily to resist the action of antiseptics.

"My experience, indeed, goes to show that, whereas non-sporing bacteria of the typhoid fever type are sterilized in half a minute with the same concentration, anthrax spores are only sterilized in from five to ten minutes. But in dealing with water supplies one does not expect to find anthrax at all; and, therefore, for practical purposes, that is for the purpose of avoiding presumable outbreak or disease, one is justified in arranging for the expulsion of the types of bacteria which are likely to occur. The sterilization could at a greater cost be applied to the spore-bearing bacteria as well, but in view of the high improbability of a dangerous contamination from the spore-bearing varieties, it is sufficient to confine ourselves to the extermination of the typhoid and cholera types.

"There are several ways in which ozonized air may be applied to bacteria destruction in water, the only conditions necessary for success being that the ozone be present in sufficient concentration, and that the ozone be brought really intimately into contact with the water itself. This point is particularly important, because ozone is very slightly soluble in water; and if the contact or mixture of the gases and the liquid is not sufficiently intimate sterilization will not be effected."

Ozonization in the Tropics.

Since the American occupation of the Philippines more attention has been given than heretofore to the subject of hygienic water supplies in the tropics; and studies in Manila have revealed the fact that ozonization offers the only means of obtaining an absolutely pure and safe water for cities in these regions. Major Case, who had charge of the first investigations into this subject, told the writer that there are scores of micro-organisms capable of producing dysentery, which have their habitat in the brushlands of the Manila watershed, and which, therefore, unlike typhoid and cholera germs, breed and multiply without human intervention. Since then Ohno reports (Philippine Jour. of Science, Vol. I., No. 9, 1906) having found in Manila fifteen varieties of dysentery bacilli, all shading into one another, but distinguishable by various tests. In addition to these organisms, belonging to the lowest group of the plant kingdom, further investigation has revealed others belonging to the animal kingdom—amœbæ of various forms, some so small and thread-like that they pass through the finest filtering material. To these is ascribed the common intestinal disease, known in the Philippines as amœbic dysentery, which is usually accompanied by liver abscesses. Ozonization presents itself as the only remedy for this form of water pollution.

It is worthy of remark in this connection that many intestinal parasites are carried as eggs or larvæ into the digestive tract by the water drunk, where they develop and remain during long periods.

Chemical Composition Improved.

The action of ozone on the chemical composition of water, already referred to, in some cases may be almost as important as its action on bacteria. This has been the subject of searching tests, which have demonstrated that ozone improves the chemical composition of water. The report of Dr. Rivas, already quoted, as well as those of other experts, show that organic matters held in solution—the products of animal and vegetable decay—are largely oxidized by ozone, and pass for the most part out of the water in the form of gas. The destruction of dissolved organic matter by ozone is often accompanied by a beautiful phosphorescent display, which is bright and prolonged in proportion to the degree of oxidizable matter present. Otto reports that with sea-water the light persists for five or six seconds, and the water "falls in a stream of fire that spreads vapors of milky aspect that are analogous to those of phosphorus." Otto reasons that in the absence of animalculæ (he obtained these results with strained sea-water) "the phosphorescence of the ocean is due to the action of ozone." After experimenting with various aqueous solutions rich in organic matter, and getting similar effects, he concludes: "The luminosity produced is caused simply by the energetic oxidation of certain organic substances contained in the water. Even with very concentrated ozone, pure water gives rise to no phosphorescence."

Sulphuretted hydrogen, so offensive to the smell and often injurious to the organism imbibing it, is converted by ozone into sulphate—an innocuous body. In the Southern States, and especially in Florida, this gas makes many waters undrinkable. They can be rendered odorless and free from taste by means of ozone.

Ammonia, derived from the decomposition of organic matter, is transformed into more stable compounds, as nitrites and nitrates, under the action of ozone, which also reduces the ratio between free and albuminoid ammonia contained in water.

Mineral substances, such as the chlorides and sulphates, are generally unaffected by ozone, although carbonate of lime is sometimes precipitated from the earthy alkaline-sulphates.

A scientific commission, appointed by the municipality of Lille, Belgium, to investigate this subject, reports that "ozonization adds to water no foreign substance injurious to those who use it. On the contrary, by reason of the great diminution of organic matter, the waters treated are less subject to subsequent pollution, and are consequently less liable to deterioration. Further, ozone, being nothing but a special molecular state of oxygen, its use has the advantage of energetically ærating the water, and rendering it more wholesome and palatable than if its mineral contents were removed."

Toxines Eliminated.

The toxines, toxalbumines and ptomanes, which have a microbic origin, were found by Messrs. Roux, Vaillard and Van Ermengem to be destroyed by ozone. One of them made a preparation of tetanus toxine of such strength that half a c.c. sufficed to kill a mouse. Subjected to the action of ozone, this toxine "became completely innocuous."

Ozone Removes Color and Odor.

Further, ozone takes out of water all disagreeable taste, color and odor. Waters containing chemical residues, salts and oxides of iron, or discolored by peaty matters, are more or less bleached or decolorized by ozone and robbed of their noxious qualities. As for the ozone itself, which is added to the water, this quickly disappears, and after a few seconds the water has neither smell nor taste of ozone.

Plants in Operation.

The process of ozone purification of water has been in practical operation at Paderborn, Germany, for upwards of five years; and Dr. Erlwein reports that as a result "typhoid fever has been practically eliminated, notwithstanding that in former times the city suffered from an epidemic of disease almost annually."

In St. Petersburg a plant capable of treating 2,500 gallons an hour is in operation. In Astrakhan it is used for mineral water; and in a large brewery in Munich, as well as one in Marseilles, the water used is sterilized by ozone, and casks and other vessels are washed in ozonized water.

A portable ozonizing outfit was in operation in one of the great military camps at Harbin during the past Russo-Japanese war.

A large part of the water supplied to Nice, France, is ozonized, and small plants have long been in use in various hospitals in Paris. In an artificial ice manufactory in Detroit, Michigan, the water used is sterilized by ozone.

Recent Advances in the Art.

The costs of ozone purification have been greatly reduced in recent years. The perfecting of electrical machines, on the one hand, has led to ever-increasing yields of the gas; while the simplification of the process, on the other, has brought about such economies in installation and operation as have put these far below the cost of building and working filters of any kind. At first, very high potentials were used, 50,000 volts being not uncommon; and dielectrics were constantly fractured under the strain. Then, for years efforts were made, and large sums of money spent, to get away from dielectrics. As the art progressed it was found that lower voltages could be employed; and, new dielectrics having been invented capable of withstanding the lessened strain, there has resulted an ozonizer that is as simple to make and as reliable in operation as any other standard electrical machine.

In all the early apparatus, and still in many European models, it was necessary that the air admitted to ozonization be dried, usually by refrigeration; and this involved the use of a costly machine that was ever liable to get out of order, and that absorbed about as much power as the ozonizer itself. This has been done away with. Then it was, and generally is, the custom to force the ozonized air, by pressure, into contact with the water under treatment, sometimes against a head of thirty feet, again necessitating the use of an unreliable and energy-devouring machine. This, too, has been abolished in the Howard-Bridge system in favor of letting the water, by its own suction action, draw into its current the ozone needed for its purification.

Ozone Tests by New York City.

What the elimination of these two machines means to the future of ozone purification may be inferred from the following extract from the report of Mr. I. M. de Verona, M. Am. Soc. C.E., chief engineer of the Department of Water Supply of the city of New York, on a series of tests made by the officials of that city of an ozonizing plant in 1907, quoted in "Engineering News," November 21, 1907:—

"The experiments showed that of the amount of K.W. energy used, about one-quarter was consumed by the refrigerating machine, **one-quarter by the transformer and ozonizer**, and one-half by the compressor. It appeared that the color might be reduced from about 15 to about 5, and bacteria from about 100 to about 7, by the use of about 3,500 grams of ozone per 1,000,000 gals., with an expenditure of about 800 K.W. hr. electrical energy—200 of which were expended on the ozonizer and transformer. With electrical energy costing 2½ cents per K.W. hr. (a low price), it appears that under the conditions of the experiments the process was costing about $20 per 1,000,000 gals., of which perhaps $5 represented the cost of ozone and the other $15 were chargeable to drying the air and pumping it into the water."

Mr. de Verona adds that the plant did not run a single day without stopping; but he does not mention the fact that the stoppages in every case were due to defective working either of the refrigerator or of the air-compressor. The ozonizer, although improperly constructed with copper electrodes instead of aluminum, worked with but one mishap, due to a preventible short-circuit, and an extra unit was instantly switched in.

The computation of electricity-cost at 2½ cents per kw. hour is excessive, notwithstanding Mr. de Verona's parenthetical statement as to its being low. This will be shown later.

Throughout the New York tests the ozone used was not in sufficient quantity to bring about best results In European practice the rule is to use one gram per cubic meter of water—264 gallons. This necessitates 3,785 grams of ozone per million gallons. The following data are from the unpublished report of the officials in charge of the New York demonstration, and show how widely these officials departed from accepted rules in their tests:—

Bacteria.		Grams of Ozone
Before.	After.	per Million Gallons.
220	40	2,270
110	22	2,590
160	17	2,645
120	15	2,420
140	16	2,340
140	9	2,620
210	35	2,680
200	9	2,470

Reports of numerous tests made elsewhere justify the inference that much greater numbers of bacteria in the raw water would have been destroyed had they been present; for bacteria form such an infinitesimal amount of organic matter that their complete oxidation is easily accomplished.

Cost of Ozonization.

Bearing on the important question of electricity cost, the following extract from a report by Mr. Lemuel W. Serrell, M.E., of New York, on the operation of the Philadelphia plant may fitly be quoted:—

> The cost of treating water by ozone depends entirely upon the cost of producing a K.W. hour. The ozonization plant operates under a constant load and therefore the generating machinery will operate with the greatest efficiency.
>
> The cost of generating electricity by steam varies slightly, depending upon the size of the plant and the price of coal; but operating under the above conditions of constant load the average cost should not exceed 1c. per K.W. hour, and in large units it will be less than this.

Since the development of the automobile engine, rapid advances have occurred in the development of stationary engines using oil as a motive power. Very considerable advances have likewise been made in the use of producer gas and gas engines.

At the recent St. Louis fair, an exhibition known as the "German Tyrolean Alps" was operated by an oil engine. The plant was in operation from May 1st to December 1st, during which time it delivered 588,500 K.W. hours with 60,120 gallons of oil that cost, delivered at the storage tanks at the plant, $1,803.60, an average cost for fuel of .3 of a cent per K.W. hour. The makers of this engine will give a guarantee of .4 of a cent for fuel per K.W. hour. There are other engines on the market not as well-known, which claim to produce practically the same results.

A well-known concern, manufacturing producer gas plants in connection with gas engines, will guarantee the fuel consumption per K.W. hour, with fuel at $2.25 per ton, not to exceed .2 of a cent at the switch-board.

The cost of power station labor in plants of this kind is about the same as the cost of fuel.

I do not feel that I would be giving this subject full consideration without bringing the above facts to your attention, as they put before you a possible field for the generation of power available for small-sized units, for about .6 of a cent per K.W. hour at the switch-board, interest and depreciation not included, which is fully as good if not better than the best results obtained in steam engine practice, where the units are large and all known methods of economy are made use of.

Revising, then, Mr. de Verona's figures, and computing electricity at one cent per K.W.H., the $5 per million gallons charged by him to ozone at 2½ cents per K.W.H. must be reduced to $2 per million. A further reduction of 30 per cent. to $1.40 must be made by reason of the fact, possibly unknown to Mr. de Verona, that the current used by the city officials was one of only 60 cycles frequency, instead of 100. This is the known difference in yield of ozone caused by the difference in current frequency. Still again, a reduction of 20 per cent. is called for by the fact that in these tests two step-up transformers were run in series—with great loss—in order to obtain the unexpectedly high potentials necessitated by the low frequency of the current. This brings the cost of ozone, had the experiments been conducted along well-ascertained lines, to $1 per million gallons. And the present writer, who attended some of the tests and pointed out these and other misleading improprieties at the time, ventures to go further, and assert that had the ozonizer not been improperly constructed, and the perforations in its electrodes not obstructed by oxide of copper formed on them, the yield of ozone per K.W.H. would have been at least 50 per cent. more than it was. In Philadelphia, all the foregoing conditions have been met in actual practice on a larger scale than in New York, and all the claims just made have been justified during long time-tests. Here, for example, is one bearing on bacterial efficiency, time endurance, and electrical expenditure, that may be fairly contrasted with Mr. de Verona's experience. It was conducted by Dr. Dughée, of New York, aided by the engineers of an independent electrical corporation. If the figures in the last column are reduced by 75 per cent., so as to accord with Mr. de Verona's estimate of the cost of operating refrigerating machine and air-compressor, it will be seen that in this test the ozone-cost would be but 43 cents to 53 cents per million gallons, computing electricity at one cent per K.W.H., as is fair.

Date	Water gals. per hr.	Bacteria		Electrical Expenditure K.W.H.	R per mill. gals K W.H.
		Before Ozinization	After Ozinization		
Dec. 14, 1905.......	31,200	1,500	2	6.1	196
Dec. 14, 1905.......	30,000	2,000	2	6.0	200
Dec. 14, 1905.......	30,300	2,600	4	6.0	198
Dec. 15, 1905.......	30,900	2,100	2	5.5	178
Dec. 15, 1905.......	31,300	1,000	2	5.9	188
Dec. 15, 1905.......	30,000	1,300	5	5.8	193
Dec. 18, 1905.......	29,900	5,600	4	5.6	172
Dec. 18, 1905.......	31,000	1,000	5	5.6	181
Dec. 18, 1905.......	28,500	1,200	1	5.5	193
Dec. 19, 1905.......	30,000	750	2	5.5	183
Dec. 19, 1905.......	29,000	550	4	5.6	193
Dec. 19, 1905.......	27,000	9,900	19	5.6	208
Dec. 19, 1905.......	28,000	6,000	3	5.5	197
Dec. 19, 1905.......	30,000	3,700	4	5.5	183
Dec. 20, 1905.......	29,000	2,900	1	5.5	190
Dec. 20, 1905.......	28,400	4,100	2	5.6	197
Dec. 20, 1905.......	28,400	7,100	5	5.6	197
Dec. 20, 1905.......	28,000	5,900	5	5.8	207
Dec. 21, 1905.......	29,000	8,600	13	5.5	190
Dec. 21, 1905.......	28,000	8,700	11	5.5	197
Dec. 21, 1905.......	27,000	16,400	15	5.8	215
Dec. 21, 1905.......	26,000	2,700	6	5.5	212

Some of the lake cities are getting, or about to get, electricity from Niagara Falls at a very low rate. Toronto, for instance, is to pay $18.10 per H.P. year. This is equivalent to .28 cent per H.P.H., and means ozone purification at a cost for electricity of 28 cents per million gallons. "Here's revolution for you, had we but the trick to see it!" Cheap electricity, on the other hand, has no effect on the cost of sand-filtration.

It may be mentioned here that the United Ozone Company has propositions at the present time under consideration by the authorities of two large American cities, under which guarantees are offered that ozone purification plants to treat 10 million and 40 million gallons daily can be installed in these cities at one-third the cost of slow sand filtration plants of equal capacity, and operated for at least one-half, with far greater efficiency. In one case the saving amounts in first cost to over a million dollars, and in the other to nearly a quarter of a million; while the annual saving in operating expenses will pay interest on like sums.

Cost of Filtration.

In Mr. Serrell's report, just cited, are statistics of filtration costs which may be appropriately copied here. He says:—

There are two methods of filtration in use at the present time, one known as the slow-sand filtration, the other as mechanical filtration.

Slow-sand filtration is cheaper than mechanical filtration, but the cost of installing the plant is very much greater, while the ground space occupied is enormous, the German standard for slow-sand filtration requiring one acre of ground for every 2,570,000 gallons treated in 24 hours. Such filtration plants require covers where cold weather is experienced, to prevent a too rapid formation of ice. The following statistics will give you some idea of the cost of building such plants:—

Berlin	Covered filter	$70,000 per acre.
Zurich	Open "	$42,000 " "
Zurich	Covered "	$72,000 " "
Ashland, Wisconsin	" "	$70,000 " "
Poughkeepsie, New York	Open "	$42,000 " "
Berwyn, Pennsylvania, without land	Covered "	$45,600 " "

Concrete covers usually add about $13,000 per acre.

The total cost of slow-sand filtration according to Turneaure, including interest and depreciation under ordinary conditions can be figured at $7 to $9 per million gallons. These figures are practically concurred in by other authorities.

The average cost of constructing mechanical filtration plants appears to be $14,000 per million gallons' capacity in 24 hours. These figures are concurred in by Hill, Turneaure, Fuller, Hering, and others. The cost of operation depends largely upon the amount of alum used, one grain of alum per gallon of water being considered the minimum that can be used to accomplish any results, and this increases with the amount of soluble organic matter in the water. In order to produce satisfactory bacteriological results, the alum and the water should be mixed together in settling basins and allowed to stand 3½ hours before passing through the filter. This requires considerable space for settling basins; and unless this precaution is taken mechanical filtration will not produce a removal of bacteria that can be safe to health. One of the most eminent sanitary engineers in this country once stated to me that he only knew of two mechanical filtration plants in operation in the country that were producing proper results.

Fuller places the cost of mechanical filtration at $10 per million gallons, including interest and depreciation. Hazen places the same cost at $12.50 per million gallons.

The filtration plant at Little Falls, N.J., is probably one of the best constructed and best operated plants in the country; and I am advised on reliable authority that the cost of filtration at this plant is $8 per million gallons, interest and depreciation not included. The same authority states that with alum at 1c. per pound, the cost of the alum per million gallons varies from $1.80 as a minimum to $3.

From the above tests and figures recited, it will, therefore, be seen that you have at last succeeded in purifying water by ozone, absolutely removing all the disease-breeding germs, at a cost only slightly in advance of the cost of the alum used in the mechanical filtration plants, and for less than half the total cost of mechanical filtration.

Cost, etc., of Filters at Lawrence, Mass.

Lawrence, Mass., has acquired a world-wide reputation through the experiments in sand filtration conducted there by the Massachusetts State Board of Health. While it is impossible to commend too highly the work thus done, it is nevertheless true that the results obtained and so widely circulated have given a false impression as to the general efficiency of sand filtration; and this for the reason that the results reported were obtained under the supervision of trained scientists. Every large municipal plant operated under ordinary conditions, and with such workmen as are usually employed by cities, has, without exception, failed to reach the standard set by the Massachusetts State Board of Health.

But even at Lawrence, the Mecca of American filtration devotees, the system has proved far from perfect. The first filter, completed in 1893, was an open one of the usual English type, and was "covered almost continually through the cold New England winter with from six inches to three feet of ice," so that "it became necessary to remove the cumbersome ice from the beds almost continuously." "The reduced volume which it was possible to filter, owing to the small water space between the ice and the sand, reduced correspondingly the reservoir surplus, and the few days lost in the process of scraping meant much to the available store of filtered water." Plans were, therefore, made, at some expense, for an additional filter; but these were laid aside during a prolonged effort to find another source of supply, and $5,800 was spent in driving wells, which were found inadequate. Efforts were then made to obtain a supply from some convenient lake or pond, and these failing, the State Board of Health directed the city to proceed with the construction of the filter already planned. Again, the citizens, apparently not altogether satisfied with filtration, had recourse to various pretexts for delay, until the Committee on Water Supply of the Legislature "ordered the new work begun within one week," under penalties. The city thereupon began to build the new filter, this time covered, and in December, 1907, it was put in operation. On January 3, 1908, the State Board wrote:—

"Daily examinations of the water filtered by the new Lawrence filter during the past month indicate that although the numbers of bacteria are not yet reduced to the same extent as in the water filtered by the old city filter, the reduction is such that in the opinion of the State Board of Health the water now filtered may be used for domestic purposes **if the rate of filtration is not allowed to exceed one million gallons in** twenty-four hours."

Notwithstanding this, "the free and full use of the filter had not been permitted" in the following April; and in that month the present writer, while visiting Lawrence, was informed that B. Coli were found in the effluent of the filter when operating at even this low rate.

The new filter is three-quarters of an acre in size, and its actual cost was $54,331.48. By the adoption of improved sand-washing arrangements "a reduction of cost of washing from the $5.50 to $8 per million gallons per year in the old filter to $2.50 in the new is expected." (Quotations from Mr. J. Rodney Ball in Municipal Engineering, April, 1908.)

The Lawrence filters take their water from the Merrimac River, which is moderately turbid during most of the time. The turbidity results in an excellent Schmutz-decke (mud-cover) forming on the surface of the sand; and because the filters are fairly efficient under these conditions, the State Board of Health reasons that sand filtration ought to be adopted by the city of Lynn, where the water is clear and but slightly polluted, but offensive in taste and odor in summer through algæ. In scholastic Boston this is what would be termed an interesting example of a non sequitur. In Lynn, where the practical effect will be a needless expenditure of a quarter of a million dollars, it is characterized as sheer foolishness! As, under conditions almost identical, the new sand filter at Springfield failed last year—an unusually favorable one—to remove vegetable tastes and odors from the water, and costly changes and additions have been found necessary, Lynn is probably right. Lynn believes ozonization will give better results at one-third the cost, and is resisting an effort to force the adoption of sand filtration.

Coagulation to Aid Washington's Filters.

Of the newly finished sand filters at Washington, D.C., on which $3,000,000 have been expended, it is reported by Mr. Theodore Horton (Engineering News, 56, 484-8) "that, although the coli bacilli are found in the effluent, the percentage of removal is in about the same proportion as the removal of the total number of bacteria, and that the colon bacillus is found in the filtered water of other cities, as, for instance, Lawrence, Mass." Dr. Woodward, Health Officer of the District, discussing this condition before the American Society of Civil Engineers, "believed that slow sand filtration alone was capable of giving satisfactory results as regards removal of bacteria and turbidity." Notwithstanding such "satisfactory results," it is stated (Engineering News, February 27, 1908), that "all the engineers who have had to do with both preliminary investigations and the construction and operation of the Washington filters have recommended coagulation for use at times of high turbidity." Anyone who has taken a bath in the coffee-like liquid often served in Washington since the installation of the new filters, will join in the recommendation. It may be added that every official connected with the water supply has also been trying to discover why typhoid fever continues so alarmingly prevalent in Washington since the filters were established.

Sedimentation, Coagulation and Filtration for New York.

Coagulation as an adjunct to slow sand-filtraiton, as proposed for Washington, D.C., is an innovation in the art of water purification; but this itself is to be supplemented by prolonged sedimentation in the case of New York, if the plans of Mr. de Verona are carried out. Nothing could be more eloquent than these facts of the inadequacy of sand filtration to meet the demands of modern sanitation. A generation ago, before bacteriology had become a science, there was some justification for the trust which was generally reposed in this ancient method of water purification; but now its most ardent advocates are among the first to acknowledge its insufficiency. In Engineering News for November 21, 1907, Mr. de Verona's plans, approved by Messrs. Rudolf Hering and Geo. W. Fuller, are set forth. These include, during eight months of the average year, the addition of sulphate of alumina to the water in the proportion of one grain to the gallon at a cost of $1.20 per million; the use of a sedimentation basin "holding at least 17 hours' flow"; and finally, sand-filtration at a 10,000,000 gallon rate. The cost of construction is estimated at $8,500,000, and of maintenance at $2.50 per 1,000,000 gallons. Concerning these figures it may be briefly said that there is nowhere in the world a going plant of any comparable capacity that has been built for twice this estimated cost; nor any plant, large or small, involving coagulation, sedimentation and filtration, that is operated for even double the figures here stated.

As to Mechanical Filters.

In addition to the high cost, the intelligence and scientific knowledge required to operate a mechanical filter with even moderate efficiency are well exemplified by the experiences of Mr. C. H. Cobb, superintendent of the Kankakee (Illinois) Waterworks, as told at a meeting of the Illinois Society of Engineers at Champaign, Ill., January 15, 1908, and summarized in Engineering News for January 30, 1908. Mr. Cobb relates that he "commenced dumping in the alum, and used about 3,000 pounds in one day without clearing the water properly." The water treated amounted to 1,500,000 gallons; so that, at one cent a pound, this was about $20 per million gallons for alum alone. Then he made a determination for alkalinity, and found it sufficient to neutralize only two grains of alum per gallon, while he had been using fourteen grains. No comment is made on the effect of this excess of alum on the health of the water consumers. He thereupon added lime to his water, experimenting with various amounts, and devised a number of ingenious arrangements in an attempt to secure a perfect admixture of the chemicals. Then he consulted a scientist, and by his advice changed from alum to suphate of iron, with new methods of mixing. But he found that with his "limited settling basin there was not time enough to get a satisfactory "flock" (i.e., a flocculent filtering mat); and he changed back to alum and milk of lime. By prolonged experiment he was able to reduce the alum-cost from $15 or $20 to $5 or $6 per diem; but results were not entirely satisfactory, and he found it desirable, as turbidity changed, to alternate between iron and alum. Such a scheme, left to an ordinary workman, might work without injury to the health of the community, but there is nothing sure about it. Mr. Cobb found that as "with the majority of filtering plants he had visited," he was "too short of settling basin area," a defect which he chiefly ascribes to the large first cost of such basins. Yet his capacity was 50 x 50 x 16 ft.—about 300,000 gallons in a plant designed to treat 1,500,000 gallons a day. He tells how he kept a daily record "of the turbidity, alkalinity and color of both raw and filtered water," and adds: "I also test frequently to see that I do not get a caustic alkalinity by the use of too much lime," which would appear a very necessary precaution, having due regard to the mucous membranes of his patients—or, rather, customers. The bacterial removal he reports as being 96 to 98 per cent.; and he considers that "this is about as good as can be done from day to day with any filtering plant." It is probably a good deal better; but, applied to such waters as the Schuylkill, where Dr. Rivas found 3,000,000 bacteria per c.c., this standard would leave 12,000 bacteria per c.c. at 96 per cent., or 6,000 per c.c. at 98 per cent.—a matter of six to twelve million bacteria in a goblet of water! As shown by Dr. Rivas, ozonization left five instead of 12,000 bacteria per c.c., and he was dealing with the sewage-polluted Schuylkill. And these five were all of the harmless varieties, which cannot be said of Mr. Cobb's 12,000.

The model village of Roebling, N.J., where neither money nor pains have been spared to secure perfect sanitation, has a mechanical filter that is probably the costliest of its kind on the market. Alum is used as a coagulant, as much as ten grains per gallon being sometimes added under the direction of an expert chemist. Last year the community suffered an epidemic of typhoid fever; and even with ten grains of alum per gallon, the filtrate contains B. Coli.

The Limitations of Sand Filtration.

The insufficiency of slow sand filtration alone as a means of giving a city pure and wholesome water with regularity and certainty is eloquently shown in the published reports of the Philadelphia Bureau of Filtration for 1904. While engaged in spending some $25,000,000 to $30,000,000 on additional sand filters, the city of Philadelphia has been operating three series of filters at Lower Roxborough, Upper Roxborough, and Belmont, and making weekly tests of their bacterial efficiency. Operated under the direct supervision of Mr. John W. Hill, one of the foremost hydraulic engineers in the country, an authority on sand filtration subjects and author of several standard works on water purification, it is to be presumed that these filters have been worked at their maximum efficiency. During the year 1904 Mr. Hill had the confidence of the city administration, and was in no way handicapped in his work. He had a well-equipped laboratory and a staff of scientists to aid him; and the fearful typhoid conditions of the city, which had become chronic and a scandal to the whole State of Pennsylvania, permitted and justified the greatest liberality in expenditures on these filtration plants. As chief engineer of the works designed to treat the whole of Philadelphia's enormous water consumption, Mr. Hill had every incentive to operate the system of filtration plants at their highest efficiency in order to justify the expenditure of $25,000,000 to $30,000,000 on the new filtration system. It is certain, therefore, that the highest possible showing has been made in his official report of the operations of the Roxborough and Belmont filters.

Poor Work of Philadelphia Filters.

In estimating the efficiency of a system of water purification it is futile to take an isolated "best result" as indicative of its degree of safety to the water consumer. This, however, seems to be the usual course; and claims are broadly made by the advocates of sand filtration that a bacterial removal of 99 per cent. and upwards may be achieved by this process. As a chain is no stronger than its weakest link, a system of water purification is no more efficient than its minimum bacterial showing. This, in the Philadelphia filters, is stated in the annual report to be as low as 33·33 per cent. This is in the report of the Upper Roxborough filter, and is a comparison between the filtered water and that flowing from the sedimentation reservoir. In the case of the Lower Roxborough filters, the minimum bacterial reduction is 73·47 per cent., and compares the filtered water with that flowing from the preliminary filters. In the Belmont filters the minimum bacterial reduction is 95·7 per cent. in the water flowing from the sedimentation basins, and 95.6 per cent. in the water taken from the Schuylkill River above Fairmount Dam.

In Germany it is forbidden by law to operate filters which leave more than 100 bacteria per c.c. in the effluent water. In Philadelphia more than 3,800 bacteria are sometimes left in the water after sand filtration, and the water thus contaminated is distributed to consumers. To assume that these 3,800 bacteria are harmless is a gratuitous assumption. When we remember that the Schuylkill River contains the sewage of the many towns along its banks, we may safely venture the assertion that a large proportion of this living matter is of intestinal origin. A cubic centimeter is, roughly, twenty drops—about as much as would adhere to one's finger if dipped in the water. A goblet of water holding a litre would, therefore, contain nearly 4,000,000 bacteria!

Here are statistics taken from the Annual Report of the Bureau of Filtration for 1904:—

Lower Roxborough.

Week ending January 30th, 1904.

Filter.	Bacteria in Filtered Water.
1	990
2	3,000
3	580
4	1,500
5	3,400

Average after double filtration, 1,900.

Upper Roxborough.

Week ending January 30th, 1904.

Filter.	Bacteria in Filtered Water.
1	2,400
2	410
3	58
4	150
5	3,800
6	860
7	180
8	1,800

Average of filters after sedimentation, 1,200.

The cost of operating the above filters is stated to be as follows:—

Lower Roxborough.

No. of Filters.	Gallons per Day.	(p. 8.) Cost per Million.
5	8,432,000	$4.56

Upper Roxborough.

No. of Filters.	Gallons per Day.	(p. 12.) Cost per Million.
8	9,530,000	$5.32

The interest and depreciation charges on Philadelphia's filter plants have been authoritatively stated to be $7.50 per million gallons. To achieve the foregoing results, therefore, the city is paying $12.82 per million gallons filtered at Upper Roxborough, and $12.06 at Lower Roxborough.

B. Coli Communis in Filtered Water.

If bacterial reduction marks the efficiency of a water purification process, ozonization may be said to stand to sand filtration as 19 to 3,800, the highest figures shown by the two methods of water treatment in the same town. But such a comparison, enormously favorable to ozonization, would still do it an injustice; for, unlike sand filtration, ozone is selective in its action, and destroys the disease-breeding germs first and the innocuous bacteria last. The 19 bacteria left in the ozonized water were all of the variety known as the hay bacillus (B. Subtilis), a vegetable organism so tenacious of life that it can be boiled for an hour without destroying it. This bacillus, however, is absolutely without effect when taken into the human system. On the other hand, the 3,800 bacteria left in the sand-filtered water are of numerous kinds, disease-breeding as well as harmless. The colon bacillus, which originates in the human intestines, and is, therefore, an indication of unchanged sewage pollution, is frankly admitted by Mr. Hill to have been found in the water after passing through Roxborough and Belmont filters. Indeed, it could hardly be otherwise. So small are these bacilli that, laid end to end, 12,000 of them would make a line but one inch long; there are said to be 1,000 million of them in one gram of fœcal matter, and every human being daily discharges 200 thousand million of these micro-organisms, often into the water which we or others have to drink. The subject may be nauseating, but "it is a condition and not a theory that confronts us." The 19 germs left in the ozonized water may be multiplied a millionfold and drunk with impunity. It is a clean organism, having its origin in dry grass or hay. Mr. Hill frankly states (page 123, Report of the Bureau of Filtration) that "the presence of the bacillus Coli Communis in samples of raw and filtered water was determined in quantities ranging from 10 to 50 cubic centimeters, in **all samples** from the effluent of filters and from the clear water basins."

If not another word be added to this statement of Mr. Hill's, it is in itself an alarming admission and a most serious impeachment of the art of slow sand filtration as practised in America under the most favorable conditions.

But the colon bacillus is not the only objectionable germ left among the 3,800 in the filtered water supplied to Philadelphia. There are others infinitely more dangerous; and many diseases of obscure origin are now being traced by physicians to water-borne bacteria. There is no doubt that the so-called summer complaints which affect so many people, especially young children, have a microbic origin. Cholera morbus and diarrhœa have thus been traced; and Dr. A. E. Taylor, working in South Gippsland, Australia, as Ohno in Manilla, traced dysentery to a motile bacillus in water that was being drunk by the inhabitants. Since none but harmless bacteria are left in ozonized water, it is manifest that these rarely-recognized disease germs are all destroyed.

What Hygienists Say of Filtration.

That sand filtration is unable to meet the requirements of modern sanitation is abundantly shown by the following testimony of hygienists and water engineers in Europe and America:—

DR. M. THOINOT,—Professor, Paris Medical College. After having made a study of several epidemics of typhoid fever occasioned by the use of water taken from chalk formations, Dr. Thoinot contributes an article on "springs in the chalk formation and typhoid fever" to La Presse Medicale, February 14th, 1900, p. 81, in which he says:—

"We do not know at present a single system of filter capable of giving on a large scale excellent results permanently, and when I am told that by filtration on a large scale the number of bacteria present in the river water has been reduced by 80 or 90 per cent., this brilliant result means to me that of the 100 pathogenic germs, 100 Elberth typhoid bacilli, if you like, which existed before filtration, 10 or 20 persist after filtration, which does not make me feel safe. I reflect that all the soluble toxical compounds, which the unavoidable fœcal matter, urine, refuse water, etc., have carried into the river, have passed the filter, at least partially, and are represented in my tumbler."

PROF. PERCY FRANKLAND.—("Micro-Organisms in Water," p. 120, et., seq.), reporting on the Hamburg cholera outbreak, quotes Professor Koch as saying that the outbreak was due "to the fact that this imperfectly filtered water was largely diluted by that which had been efficiently filtered;" and he continues, "the responsibility which we have seen attaches to this treatment of water (slow-sand filtration) cannot be exaggerated, for whilst when efficiently pursued it forms a most important barrier to the dissemination of disease germs, the slightest imperfection in its manipulation is a constant menace during any epidemic."

DR. P. MIGUEL and MR. R. GAMBIER,—in their Traité de Bacteriologie Pure et Appliqué, saying that "Filtration is not sterilization, it is a makeshift which can be improved upon," make the following additional statement:—

"Amongst the processes recommended to eliminate bacteria from water, some resolve the problem only approximately; sand filtration belongs to the number; it may reach a co-efficient of purification of 99.7 per cent. As pathogenic germs are less numerous in drinking water than inoffensive ones, is it probable that the filters will retain them in preference to the others?"

JAMES H. FUERTES,—American Society of Civil Engineers, in "Water and Public Health," has arranged in two diagrams statistical data of the typhoid death rate with different kinds of water. In these he attributes 20 per cent. of the typhoid death rate to filtered water.

FRANKEL and PIEFKE.—The experiments of Frankel and Piefke, quoted by Professor Frankland, ("Micro-Organisms in Water," p. 157), with specially constructed sand filters, furnished the proof that "the sand filters even under the most favorable conditions of working do not form a complete obstacle to the passage of micro-organisms. Thus, even when the rate of filtration was reduced to a minimum (25 mm. per hour) some, although very few, colonies of bacillus violaceous were obtained from the filtrate. Again in similar experiments in which cholera and typhoid bacilli were purposely added to the unfiltered water, these were also met with, in greatly diminished numbers, of course, in the filtrate; and it is worthy of note that the cholera appeared to be more completely retained by the filter than the typhoid bacilli."

PROFESSOR WEYL, (Berlin).—Experimenting with water such as the Spree, which contained from 16,000 to 18,000 bacteria per c.c., and testing both ozone purification and sand filtration, concluded, "that water can be treated more economically with ozone and with greater efficiency than by sand filtration, which is costly to build and to work."

JOHN W. HILL, ex-Chief of the Bureau of Filtration, Philadelphia, is quoted in the "North American," of July 1st, 1904, as saying:—"The only thing that we can figure on in behalf of filtered water in any city is a reduction of the typhoid fever rate."

Mr. Hill also states in his work on Public Water Supplies:—"Some writers in their enthusiasm have declared that sand-filters properly constructed and operated will furnish pure water. This is a mistake. No filter operated upon a practical basis has ever furnished pure water."

GEORGE W. FULLER, an eminent sanitary expert, states in The Transactions of the American Society of Civil Engineers:—"While, as is well-known, in the majority of cases mechanical filters have not been operated in a manner to produce uniformly good results, it is a fact which does not seem to be appreciated by many, that the majority of the larger slow sand-filters in this country that have been operated for several years have also failed to reach the goal which may be expected of them, as is noted by any one who takes the trouble to examine carefully the typhoid sources in cities which have slow sand-filters, such as Poughkeepsie, Hudson and Little Falls, N.Y.; Ashland, Wis.; and Rock Island, Ill.

ALLEN HAZEN, in a paper read at the Sanitary Conference of the Health Officers of Connecticut at New Haven, December 17th, 1903, says:—"Most of the filters that have been installed in this country have failed at times more or less, some of them have failed habitually and disastrously, with others the failures have been occasional and slight, and some have not failed at all. By failing, I mean the water has been sent out from them considerably short of the standard of purity established by reasonably well constructed and operated filters."

THE CITY OF ROTTERDAM, HOLLAND, has one of the best filtration plants ever constructed, the cost of operation, maintenance, and other charges being a little over $15 per million. For several months in the early part of 1903 the city was placarded with notices, and the newspapers contained daily advertisements, warning the people not to use the water without first boiling it, as it was contaminated with typhoid germs.

The late **PROFESSOR E. ANDREOLI**, (London):—"Sand filtration on a large scale does not totally purify the water supplied to towns and villages. Small filters are very inefficient for individual purposes."

EMILE GUARINI; (Scientific American, September 2nd, 1905):—"Experience has shown that filtration is not always an adequate way of sterilization."

DR. CALMETTE, Director of the Pasteur Institute of Lille, Professor of the Faculty of Medicine at Lille:—"Sand filtration simply improves drinking water, but never gives a sufficient security."

DR. CLIFFORD RICHARDSON, Director of the New York Testing Laboratory, Long Island City, New York:—"I may remark that while slow sand-filtration has been extremely satisfactory as applied to water supplies on a large scale in the past, and while it is well-known that slow sand-filtration will, when conducted under proper supervision, remove a high percentage of the bacteria present in the unfiltered water, the typhoid fever death rate in cities where such filters have been installed has not been reduced more than 70 or 80 per cent. While some typhoid fever must always originate from contact and dust, it is hardly possible that from 20 to 30 per cent. should be attributable to such sources, especially when it can be shown that where the water supply, although a very badly contaminated one, is purified with ozone, the death rate can be reduced to the very lowest."

DR. A. E. JOHNSON, of Wilmington, Delaware, who has for several years past been experimenting with different methods of purifying water, expresses the deepest distrust of sand-filtration. "I am satisfied," he says, "that water clarified by sand-filtration is even more dangerous to the public health than the same stuff before filtering. Because of its clear and sparkling appearance the public is led to believe it pure, while it may be polluted with the same deadly germs. In the first state precaution will be used by some at least, in its second none. Is a serpent less deadly because its burnished scales shine? No, the public must look for some other method of purifying water than sand-filtration if they would render polluted streams fit for drinking purposes. I am convinced that the remedy can only be found in the ozone process."

DR. H. G. VAN 't HOFF, the well-known scientist:—"Sand filtration is a delicate job, and no one will ever dare to hope that through it perfect sterilization can be reached. Sand-filtration, no matter how well it may work and how careful the supervision of it may be, in my opinion, must be inferior to ozonization, and I believe the time is not far off when one of the weightiest questions in the field of hygiene will be solved."

SIR WILLIAM CROOKES, F.R.S., and SIR WILLIAM DEWAR, F.R.S.—These eminent English bacteriologists say:—"Of the 320 daily samples taken from the general wells of the Metropolitan Water Board, (June, 1905), * * * 26 samples or 8.1 per cent. contained more than 100 microbes per c.c., and of these, 12 samples contained more than 150 microbes per c.c. The 26 excess samples contained an average of 160 microbes per c.c. * * * The average of the filtered supply (of London), has also shown an increase of microbic impurity over that of the past month. This deterioration is shown by the fact the percentage of the samples containing more than 100 microbes is nearly double that of last month. * * * The amount of organic matter in solution in the Thames-derived waters (after filtration) has increased about one half, and their color and the amount of oxygen absorbed is correspondingly greater." These variations are attributed to the heavy rain fall. (The foregoing is an extract from a report on the composition and quality of daily samples of the water supplied to London for the month ending June 30th, 1905).

MM. ERNEST MOREAU and AMBROISE RENDU:—These experts, forming a recent commission of the Municipal Council of Paris, report as follows:—"As regards filtration, the report of MM. Moreau and Rendu, supported by the authority of Humblot, of Duclaux, of Dr. Miquel and by foreign authorities, only considers it (filtration) as an expedient to which we should have recourse as rarely as possible.

Supported by experiments the authors' report says:—

1. That the spring waters of Paris are such as to need purification.
2. That sand-filtration cannot be applied to these spring waters.
3. That sand-filtration of raw water is inadequate to meet the requirements of the Public Board of Health or of salubrity, unless the output of the filters is reduced to a ridiculous degree.

To meet the conditions it is necessary to have recourse to a chemical agent, which, as we have already indicated, is ozone, concerning the employment of which the experts of the Consultative Council of the Public Health of France and those of the City of Paris are in complete accord, even in their reservations.

'"And the authors' report concluded that by adopting this method Paris will give an irreproachable character to all its waters of alimentation, which are now, every day, being more and more impeached." '—(Le Matin, December 18th, 1905).

DR. FERNAND BEZANCON, Professor and Chief of the Bacteriological Laboratory of the Medical Faculty, Paris.

In April, 1904, Dr. Bezancon tested the effluent water of the slow-sand filters of St. Maur, Paris, and found on April 14th, 1,550 colonies per c.c. of water; on April 30th, 107; on May 7th, 200; on May 10th, 120; on May 17th, 1,400; on May 28th, 600. These filters were then running at the normal rate—a little over 2,000,000 gallons per acre. The work of the filters was subsequently reduced so that they yielded less than half their estimated capacity.

DR. MIQUEL, Chief of the Micrographical Service of the Montsouris Observatory, Paris.

Early in 1905 Dr. Miquel conducted a series of tests of water flowing from the St. Maur filters and found the colon bacillus in the effluent water, thus showing that sand-filtration even when operated at a slow rate failed to remove all intestinal germs. On February 9th and 10th this water contained 100,000 colonies per liter, and the next day 130,000. The effluent from a newly-cleaned filter at St. Maur was found to have 17 colonies of B. Coli in one liter of water.

LAWRENCE, MASS.:—(Annual Report Chief Engineer, Bureau of Filtration, Philadelphia, for the year 1904, pp. 120 and 121).

"With the Lawrence city filter, and the experimental mechanical filter, using sulphate of alumina as a coagulant, the tests for the presence of B. Coli Communis in the filtered water were not only frequently positive but resulted in easily determining definite numbers of this sewage bacterium."

DR. C. FEISTMANTEL, Military Physician and Director of the garrison laboratory at Buda Pesth, says:—

' "Small filters are not to be recommended, and large filters are not to be depended upon for bacteriological control. On the contrary, ozonization is entirely dependable for the water supplies of large communities, where spring and well waters are not available in sufficient quantities, and where surface water must be sterilized." '

An English Symposium.

DR. A. SCARLYN WILSON:—At the sessional meeting of the Royal Sanitary Institute, held at Hastings, England, November, 1905, Dr. Wilson, Medical Officer of Health, Hastings, said:—' "The most effective agency in the removal of the bacteria was not the sand, but the slimy or colloidal deposit which formed upon the surface of the sand, and it was on the integrity of this layer that the efficiency of the filtration in the main depended." ' Dr. Wilson then recapitulated certain cholera and typhoid outbreaks of recent years, which clearly indicated, he said, "that sand-filtration of polluted waters, even when most carefully conducted, did not in practice remove all danger of ill results following, though the risks were reduced to a minimum thereby. Let, then, no false sense of security, bred of over-reliance in the permanent efficacy of any system of filtration, induce us to abandon any available means of protecting from pollution the sources of our water supplies."

DR. A. G. R. FOULERTON:—Dr. Foulerton, Medical Officer of Health of the East Sussex County Council, at the same session, said:—' "Sand-filtration was very often not effectual, and one heard of repeated breakdowns of the system on a large scale, Lincoln being merely the latest of a series of such happenings. That epidemic, however, was one of which it was difficult to speak in measured terms; it was only one more example of the folly of gambling against disease. On the other hand, there were still towns which must depend on filtered river water, London being a typical example. In that case it was tolerably certain that the process of filtration did break down occasionally." '

DR. RIDEAL, at the same session, discussing the question whether pressure-filters had a hygienic equivalent in the old sand-filter, observed,—' "That it had been shown that the latter, (sand-filter), could not be relied upon for giving immunity from typhoid, for in London they often had outbreaks of that disease which could only be ascribed to the drinking of Thames water. In various parts of the world where pressure-filters had been used, it had been shown that considerable reduction in the death rates had resulted; at the same time, like the sand-filter, the pressure-filter did not insure absolute immunity from typhoid. So that neither was the perfect solution of the problem. That being so, he asked whether it was not advisable that both methods should be supplemented by a process of sterilization." '

DR. D. SUMMERVILLE:—Dr. Summerville, Lecturer on Public Health, King's College, London, said:—' "They were all agreed that no method of filtration was perfect, and that it was of prime importance that pathogenic germs should be wholly cut out of a potable water supply, and that they ought to accept with some reservation the glowing accounts of the results obtained by pressure-filters. Rapid filtration under pressure increased the opportunities for the passage of microbes. * * * As Americans had admitted to him in their own country that certain pressure-filters had been a bacteriological failure, he thought it better in the present state of their knowledge to leave the question of their adoption for bacterial filtration open, and to emphasize * * * the necessity of procuring the best sources of water supplies, so that as little as possible should be left to filters." '